11 RELATIVE CONTRIBUTIONS OF STRESSORS AND THEIR CUMULATIVE IMPACT

The results of the 1995-1997 Maryland Biological Stream Survey (MBSS or Survey) can help answer important management questions about the relative impacts of different stressors on streams as well as diagnose which are acting on individual sites. MBSS results may be used to evaluate both the extent of occurrence of stressors (estimated as the percentage of stream miles having evidence of a particular stress) and the severity of their impacts (based on their relationships with the fish IBI and other biological indicators). While the previous chapters explored the extent of individual stressors and their effects on stream biological communities, this chapter begins to analyze the relative contribution of each stressor and their cumulative impact on stream degradation in Maryland.

11.1 EXTENT OF OCCURRENCE OF MAJOR STRESSORS

Across all basins sampled in the 1995-1997 MBSS, the extent of occurrence of seven major stressors was compared: urban and agricultural land use, nutrients, physical habitat degradation, lack of riparian vegetation, acidic deposition, and acid mine drainage (AMD). The associations between each stressor and IBI scores were examined to determine the value at which each stress was having a significant effect. For the purpose of this analysis, the following thresholds were used to define the presence of a particular stressor:

- Urban land use: > 25% of catchment area
- Agricultural land use: > 75% of catchment area
- Nutrients: nitrate-nitrogen concentration > 7.0 mg/l
- Physical habitat degradation: combined rating of very poor or poor for the Physical Habitat Index (see Chapter 6)
- Lack of riparian vegetation: local riparian buffer width of 0 meters
- Acidic deposition: ANC < 200 μeq/l and water chemistry indicative of atmospheric deposition as a source of acidic materials (see Chapter 7)
- Acid mine drainage: ANC < 200 μeq/l and water chemistry indicative of AMD as a source of acidic materials (see Chapter 7)

Sites affected by both AMD and acidic deposition were included in both estimates. Some important stressors, such as migration barriers, flow reductions, and temperature were not included in this comparison. For selected stressors, the thresholds were chosen to approximate the level at which impacts would occur in most situations. However, some biota may be impacted at much lower levels (e.g., data indicate that brook trout are affected by even lower levels of urban development).

Figure 11-1 shows a ranking of major stressors and their extent of occurrence across all basins sampled in the 1995-1997 MBSS. The most extensive source of stress was physical habitat degradation, which affected an estimated 52% of stream miles. Riparian vegetation was lacking from 28% of stream miles. Agricultural land uses were influential at 17% of stream miles, while urban land use was a potential stress at 12% of stream miles. Nutrient concentrations were high in 5% of stream miles statewide. Acidic deposition affected an estimated 21% of stream miles, while AMD affected 3% of stream miles. While the spatial extent of AMD is relatively small throughout the state, its severity may be great. If not mitigated, extreme acidification can prevent a stream from supporting any aquatic life. In contrast, physical habitat degradation is widespread, but its effects on more tolerant species are often minimal.

Results specific to each basin show that the prevalence of different stressors varies across the state (Figure 11-2). Low physical habitat quality appears to be a problem in all basins. Urbanization is most prevalent in the Patapsco and Potomac Washington Metro basins. Agriculture and nutrient concentrations are most important in the Middle Potomac basin. The lack of riparian vegetation is most widespread in the Patapsco and Middle Potomac basins. AMD and acidic deposition are important sources of stream degradation in the North Branch Potomac and Youghiogheny basins, where urban and agricultural influences are less important. Acidic deposition also affects areas of eastern and central Maryland. In most cases, the relative priority of stressors affecting stream ecosystems depends on the region considered.

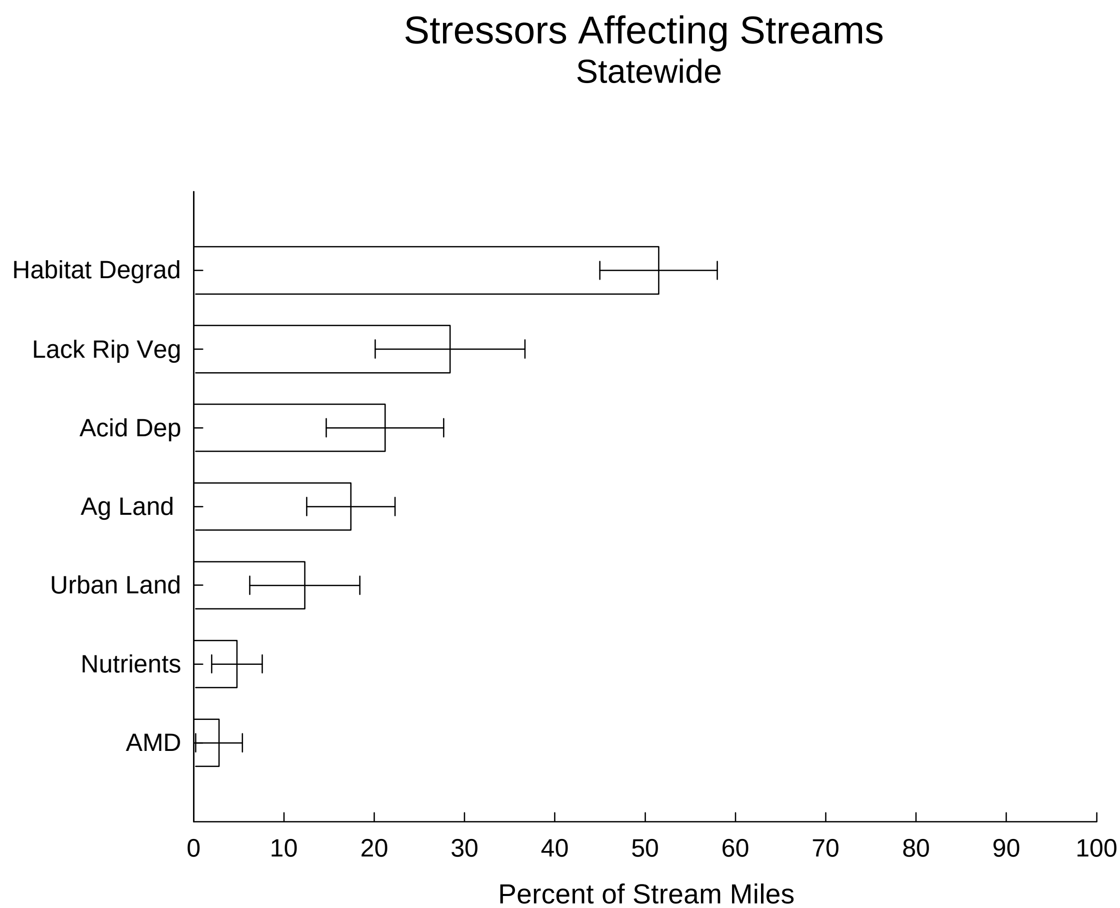


Figure 11-1. Comparative ranking of stressors affecting streams in the 1995-1997 MBSS

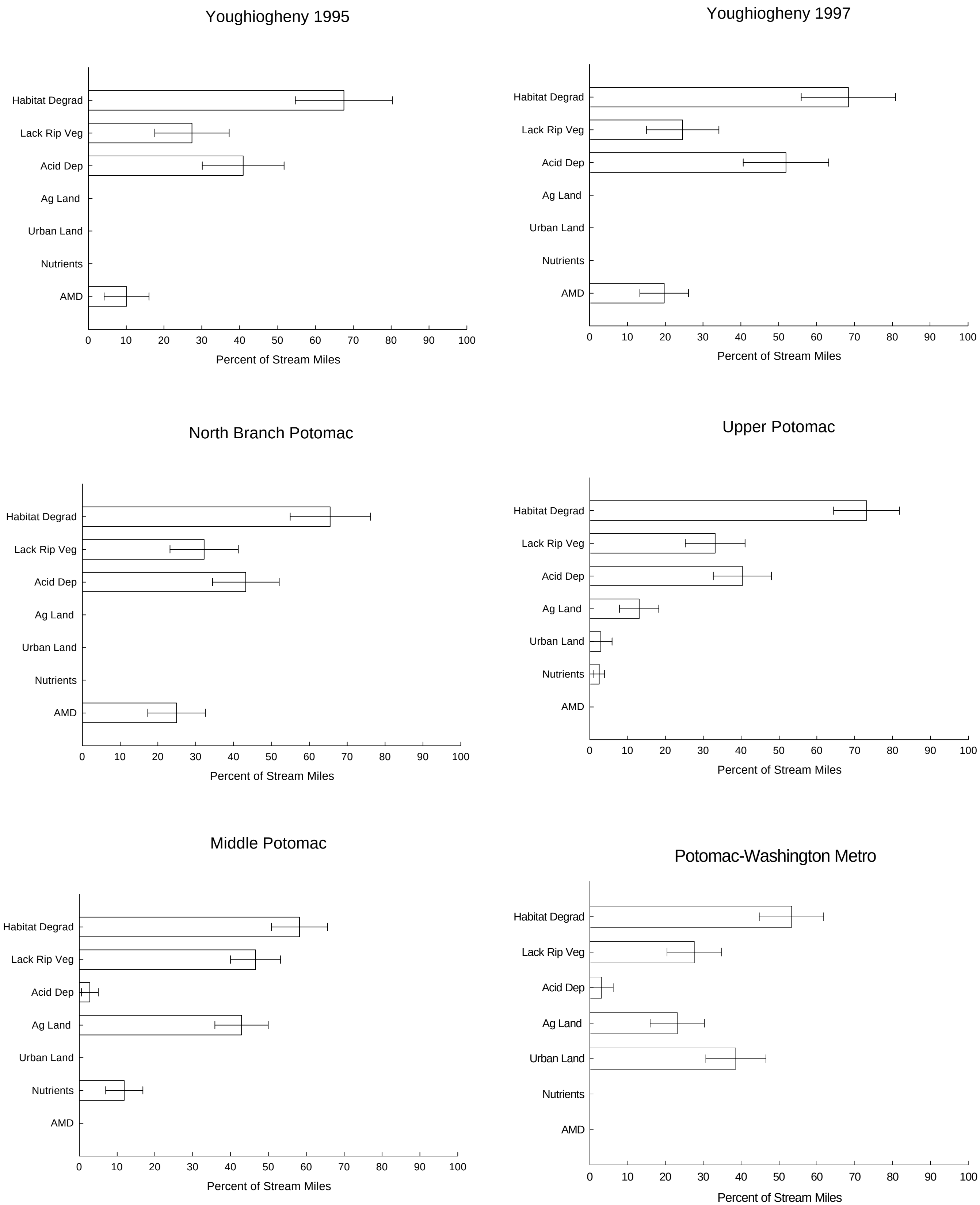


Figure 11-2. Extent of stressors affecting streams for basins sampled in the 1995-1997 MBSS

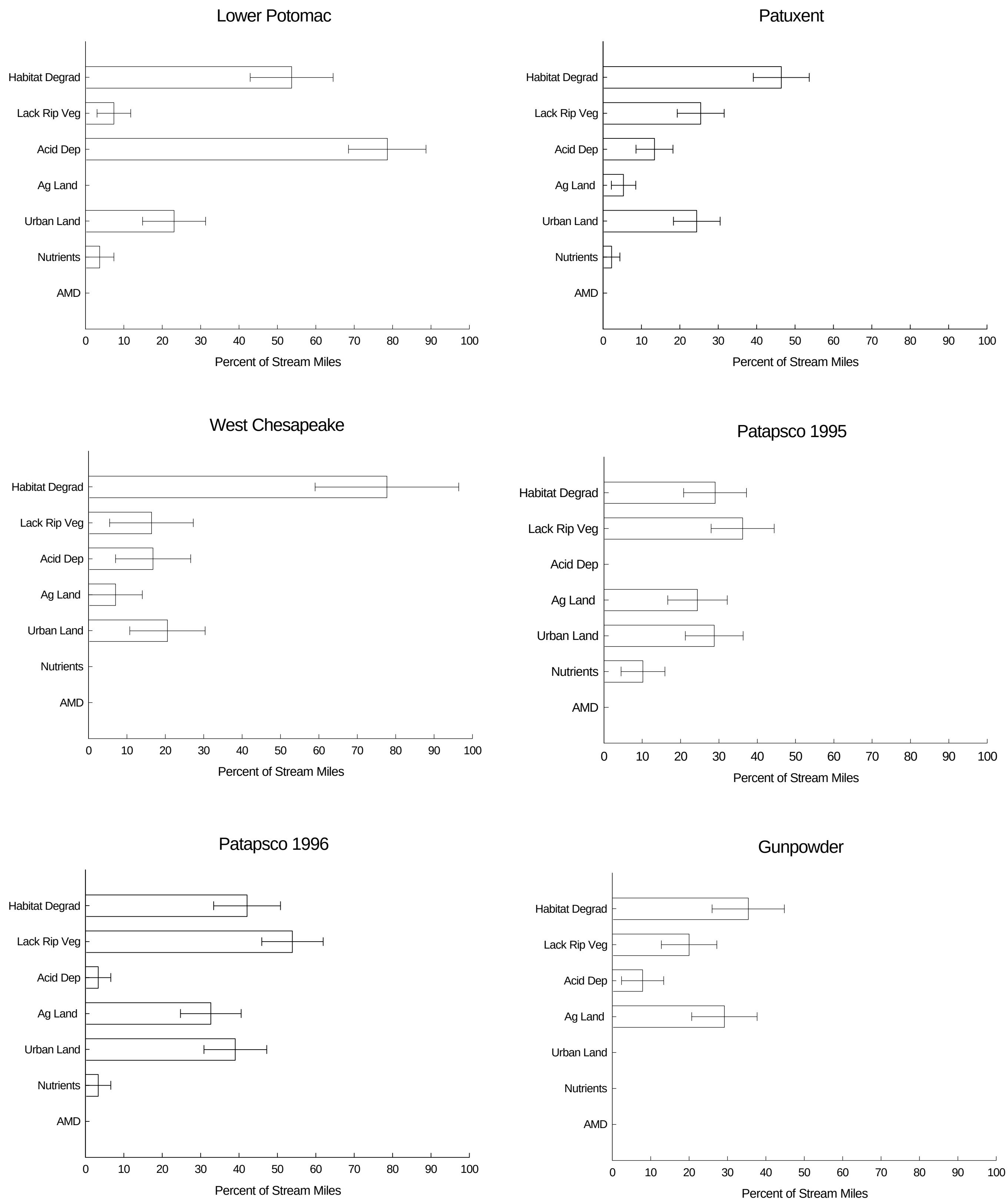
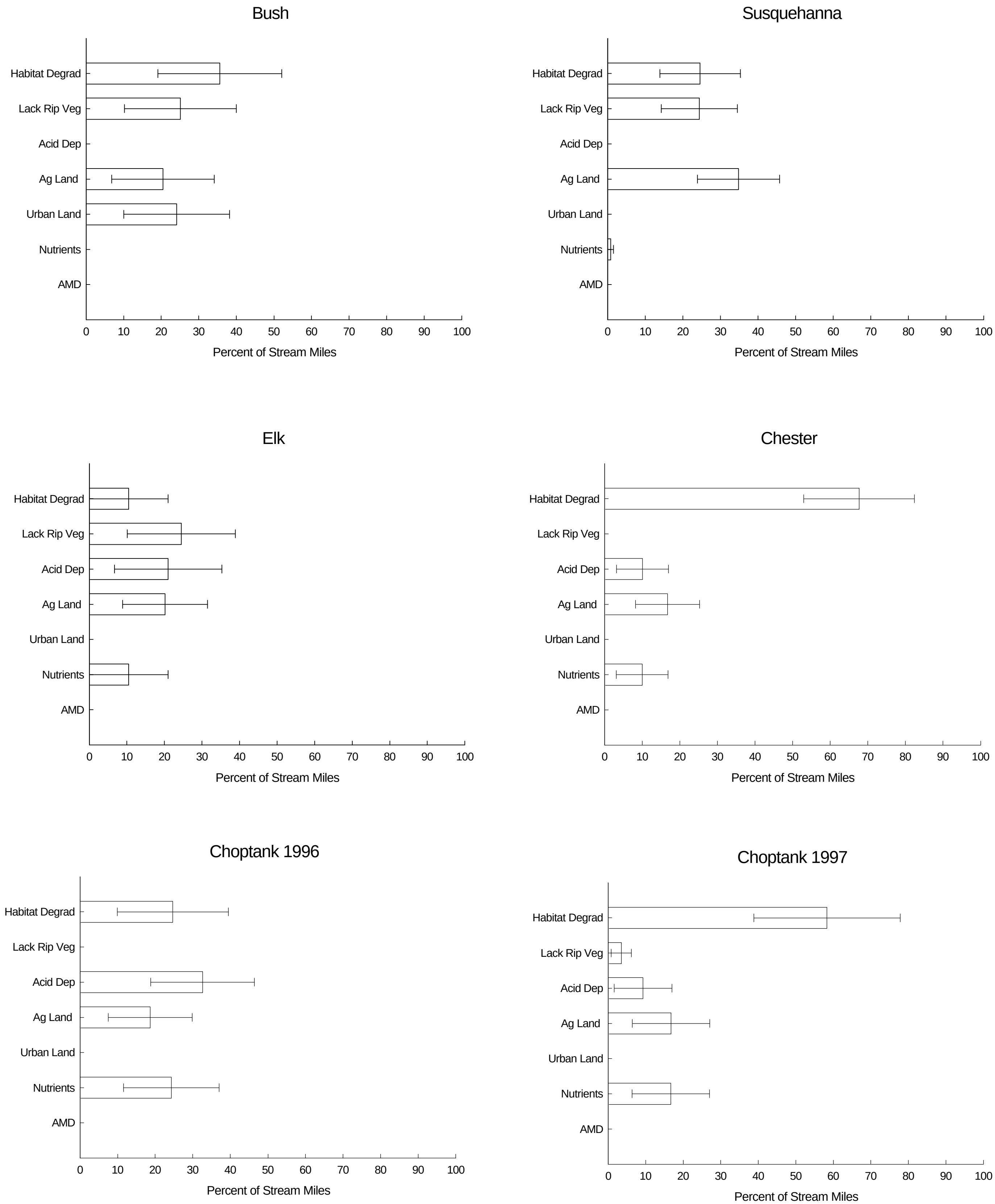


Figure 11-2. Cont'd



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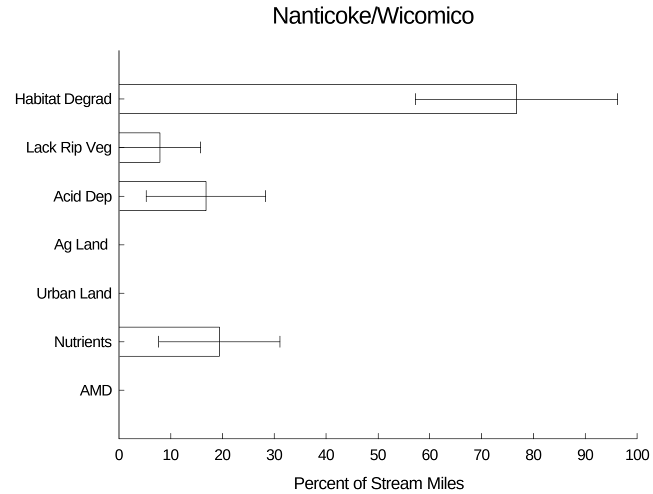

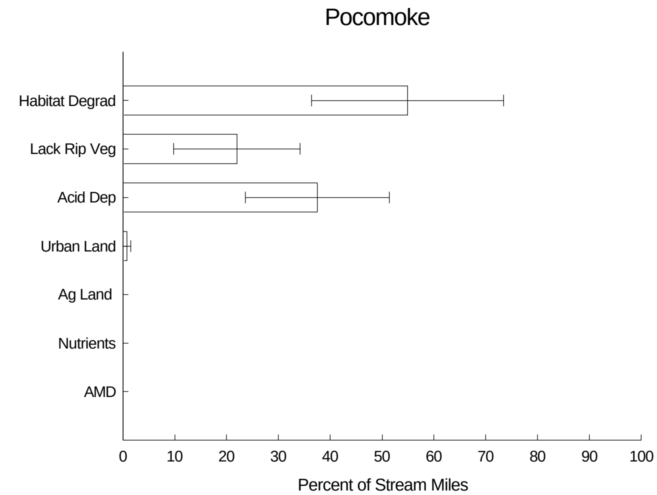

Figure 11-2. Cont'd

Individual stream sites are often affected by more than one stressor. Using the seven categories of stressors listed above, the number of stressors at each of the 905 summer sampleable sites (for which complete physical habitat data were available) were tallied. Overall, 72% of the sites sampled in the 1995-1997 MBSS were impacted by at least one of these seven stressors. Thirty-eight percent were affected by one stressor and 34% by two or more stressors (27% by two stressors, 6% by three stressors, and 1% by four stressors). The relatively frequent occurrence of multiple stressors naturally led to an investigation of the cumulative effect of these stressors upon the biological integrity of Maryland streams.

11.2 EFFECTS OF MULTIPLE STRESSORS ON IBIs

The conclusions in Section 11.1 are further supported by multiple regression analysis using each of the IBIs as the response variable and the seven stressors as indicator variables. The numerical values for the percentage of urban land use, percentage of agricultural land use, nitrate-nitrogen concentration, physical habitat degradation, and riparian buffer width were used in the model; acidic deposition and AMD were represented by categorical values based on the presence of that stressor. Statewide, fish IBI scores decreased significantly with an increase in urban land use, nitrate-nitrogen concentration, and the presence of AMD. Fish IBI scores increased significantly with an increase in agricultural land use and with improved physical habitat quality. Neither the width of riparian vegetation (as measured within the 75-m segment) nor the presence of acidic deposition were significant factors for explaining variation in fish IBI scores statewide.

The multivariate analysis was also conducted for each individual basin. Stressors that were significant in each basin are listed in Table 11-1. Poor physical habitat quality significantly affected fish IBI in 13 of the 17 basins sampled. No significant effect was observed in the West Chesapeake, Patapsco, Elk, and Choptank basins. The percentage of urban land was significant in the Middle Potomac, Potomac Washington Metro, and Patapsco basins. The percentage of agricultural land was significant in the Middle Potomac, West Chesapeake, Gunpowder, Chester, Choptank, and Nanticoke/Wicomico basins. Nutrients were significant in the Middle Potomac basin. Acidic deposition was significant in the North Branch Potomac and Choptank basins. AMD was significant in the North Branch Potomac basin. In combination with the other factors in the model, the absence of local riparian vegetation was not a significant stressor upon fish IBI in any of the basins sampled. This may be a result of the fact that physical habitat quality and nutrient concentrations (which often accompany riparian vegetation loss) are better indicators of stream degradation. Also, our local measure of riparian buffer width adequately represent the role of riparian vegetation, as it does not assess conditions upstream of the site. In fact, other analysis of Survey data has demonstrated a clear link between fish IBI scores and upstream riparian condition at the watershed level (Roth et al. 1998). None of the seven stressors were significant in the Elk basin. This may reflect the relatively good condition of streams in this basin with 38% of stream miles rated good and no stream miles rated very poor.

Table 11-1. Stressors significantly affecting biotic integrity (based on multiple regression models of stressors against fish IBI scores), by basin for the 1995-1997 MBSS

	% Urban Land	% Agricultural Land	Nutrients	Physical Habitat Quality	Acid Mine Drainage	Acid Deposition	Riparian Buffer Width
Youghiogheny				X			
North Branch Potomac				X	X	X	
Upper Potomac				X			
Middle Potomac	X	X	X	X			
Potomac Washington Metro	X			X			
Lower Potomac				X			
Patuxent				X			
West Chesapeake		X					
Patapsco	X						
Gunpowder		X		X			
Bush				X			
Susquehanna				X			
Elk							
Chester		X		X			
Choptank		X				X	
Nanticoke/Wicomico		X		X			
Pocomoke				X			

It is likely that stressors significantly affecting fish IBI are most deleterious where a stressor is present in a large percentage of stream miles. Adverse effects may also be important in basins where a particular stressor has a severe impact on fish IBI scores, but is present in only a small percentage of stream miles. Physical habitat degradation was the prevalent stressor in 11 of the basins sampled. It had a significant impact upon fish IBI scores in 10 of these basins: the Youghiogheny, North Branch Potomac, Upper Potomac, Middle Potomac, Potomac Washington Metro, Patuxent, Gunpowder, Bush, Nanticoke/Wicomico, and Pocomoke basins. The percentage of urban land use in the catchment area was a significant stressor in the two basins with the most stream miles draining greater than 25% urban land: the Potomac Washington Metro and Patapsco basins. Nitrate-nitrogen was a significant stressor in the Middle Potomac basin, even though it was only present at elevated levels in 12% of the stream miles in that basin. This result indicates that nitrogen levels greater than 7.0 mg/l may have a drastic impact on fish IBI, even if the problem is not widespread. In the North Branch Potomac basin, acidic deposition and AMD were both present in greater than 25% of the stream miles. In this basin, both acid sources had a significant effect upon fish IBI.

Statewide, benthic IBI scores decreased significantly with an increase in urban land use and with the presence of AMD. Benthic IBI scores increased significantly with improved physical habitat quality and increased riparian buffer width. Surprisingly, benthic IBI scores also increased with the presence of acidic deposition. As discussed in Chapter 9, both the benthic IBI and the incidence of acidic deposition increased with the amount of forested land use in a watershed. Thus, it is expected that benthic IBI and acidic deposition would be positively correlated. Neither the percentage of agricultural land or the concentration of nitrogen were significantly correlated with the fish IBI in the multiple regression model.

Stressors that were significantly correlated to the benthic IBI are listed in Table 11-2. None of the seven stressors were significantly correlated to benthic IBI in nine of the basins sampled: the Upper Potomac, Middle Potomac, Lower Potomac, West Chesapeake, Gunpowder, Susquehanna, Elk, Nanticoke/Wicomico, and Pocomoke. Physical habitat quality was significantly related to the benthic IBI only in the Patapsco and Chester basins (a marked contrast to this parameter’s strong relationship to the fish IBI in many

Table 11-2. Stressors significantly affecting biotic integrity (based on multiple regression models of stressors against benthic IBI scores), by basin for the 1995-1997 MBSS

	% Urban Land	% Agricultural Land	Nutrients	Physical Habitat Quality	Acid Mine Drainage	Acid Deposition	Riparian Buffer Width
Youghiogheny					X		
North Branch Potomac	X				X		
Upper Potomac							
Middle Potomac							
Potomac Washington Metro	X						
Lower Potomac							
Patuxent	X						
West Chesapeake							
Patapsco	X			X			
Gunpowder							
Bush	X						
Susquehanna							
Elk							
Chester				X			X
Choptank							X
Nanticoke/Wicomico							
Pocomoke							

basins). The percentage of urban land was significantly related to the benthic IBI in the North Branch Potomac, Potomac Washington Metro, Patuxent, Patapsco, and Bush basins. Riparian buffer width was significantly correlated to the benthic IBI in the Chester and Choptank basins. As with the fish IBI, the benthic IBI showed a significant correlation to AMD in the Youghiogheny and North Branch Potomac basins.

11.3 INFLUENCE OF STRESSORS AT INDIVIDUAL SITES

MBSS data can be used to detect stream degradation at individual sites and to identify the stressors contributing to degradation. This is relevant to State efforts to identify streams in need of restoration and to identify impaired waters as candidates for 303(d) listing. It should be noted that although the random statewide design provides accurate estimates of the number of stream miles that are degraded, only those sites that have actually been sampled have the potential to be identified here as degraded.

Analyzing for the effects of stressors at particular sites is a multi-step process that uses biological, physical, and chemical data. In this analysis, the fish IBI and benthic IBI were first used to identify candidate degraded sites (e.g., fish IBI or benthic IBI rating of poor to very poor). Then, field observations and site-specific data on water chemistry, watershed land use, and physical habitat conditions were used to determine the stressors (i.e., human activities) likely causing degradation. Finally, site-specific data were examined to rule out natural factors that may contribute to low indicator scores. Note that analysis was based solely on the MBSS data sets. Examining ancillary information, including previous studies and local knowledge of site conditions, can be a useful additional stage to better understand the factors affecting individual streams.

For the 1995-1997 MBSS, 203 sites rated either poor or very poor for both the fish and benthic IBIs. Another 175 sites

rated poor or very poor for the benthic IBI and either fair or good for the fish IBI, while 73 sites rated poor or very poor for the fish IBI and either fair or good for the benthic IBI. There were 88 sites that were rated poor or very poor for the benthic IBI and were not rated for the fish IBI. Altogether, there were a total of 539 sites scrutinized for potential stressors. For each site, physical and chemical data were examined and compiled into a matrix. Parameter values above or below the following threshold levels were considered as possible indicators of stress:

- Physical Habitat Index score < 42 (poor to very poor)
- Hilsenhoff Index > 6.0 (poor to very poor)

- Urban land use > 25% of catchment area
- Agricultural land use > 75% of catchment area
- Spring pH < 5
- Summer pH < 5
- ANC < 200 μeq/l
- Nitrate-nitrogen > 2 mg/l
- DO < 5 ppm
- Sulfate > 24 mg/l
- DOC > 8.0 ppm
- Presence of a surface mine
- Presence of a landfill
- Channelization
- Presence of a storm drain
- Presence of effluent discharge
- Presence of a beaver pond
- Instream habitat score < 11 (out of 20 points)
- Epifaunal substrate score < 11
- Velocity/depth diversity score < 11
- Pool/glide/eddy quality score < 11
- Riffle/run quality score < 11
- Channel alteration score < 11
- Bank stability score < 11
- Embeddedness > 75%
- Channel flow status < 30%
- Shading < 30%
- Riparian buffer width < 15 m

Remoteness score < 11

- Aesthetics score < 11
- Maximum depth < 20 cm
- Average thalweg depth < 20 cm

Also included in the matrix are several variables that provided additional information on site conditions and location. These variables include:

- Catchment area (acres)
- Whether any fish were captured at the site
- Whether the site is a brook trout stream
- Whether the site is a blackwater stream
- Acid source, if present
- Riparian buffer land type
- Land use adjacent to riparian buffer
- Type of stream blockage, if present
- Stream name
- Maryland 8-digit watershed code
- Watershed name
- Latitude and Longitude
- Stream order

A matrix was compiled including these parameters, additional explanatory variables, and locational information for all 539 sites with a fish or benthic IBI score rated as poor to very poor. These results are reported in Appendix F.